Probing the sea contribution to the proton's spin

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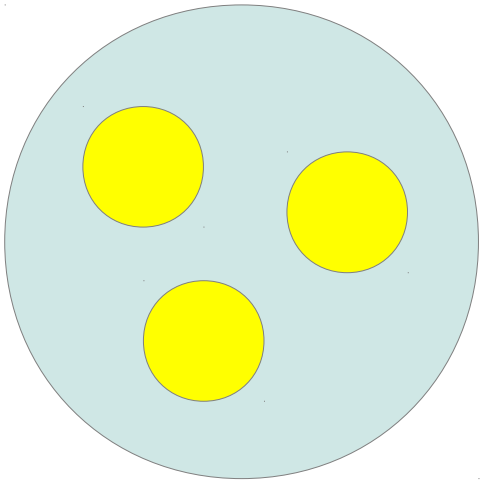
Outline

- Physics Motivation
- Forward W A_L analysis detector upgrade
- Analysis challenges
- Results

Proton spin

- The proton's spin is not simply a summation of quark spin states within the nucleon
  - First measured 20 years ago
  - 'Spin crisis'
- 20+ years of investigation through (SI)DIS
  - Brought us a broader understanding...



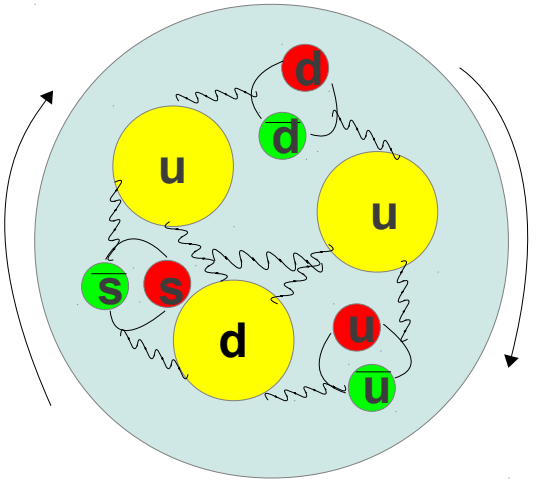
Spin = ½
u+u+d ≠ ½

quark ang.mom

Sum Rule: ½ = ½ΔΣ+½ΔG+½L_z

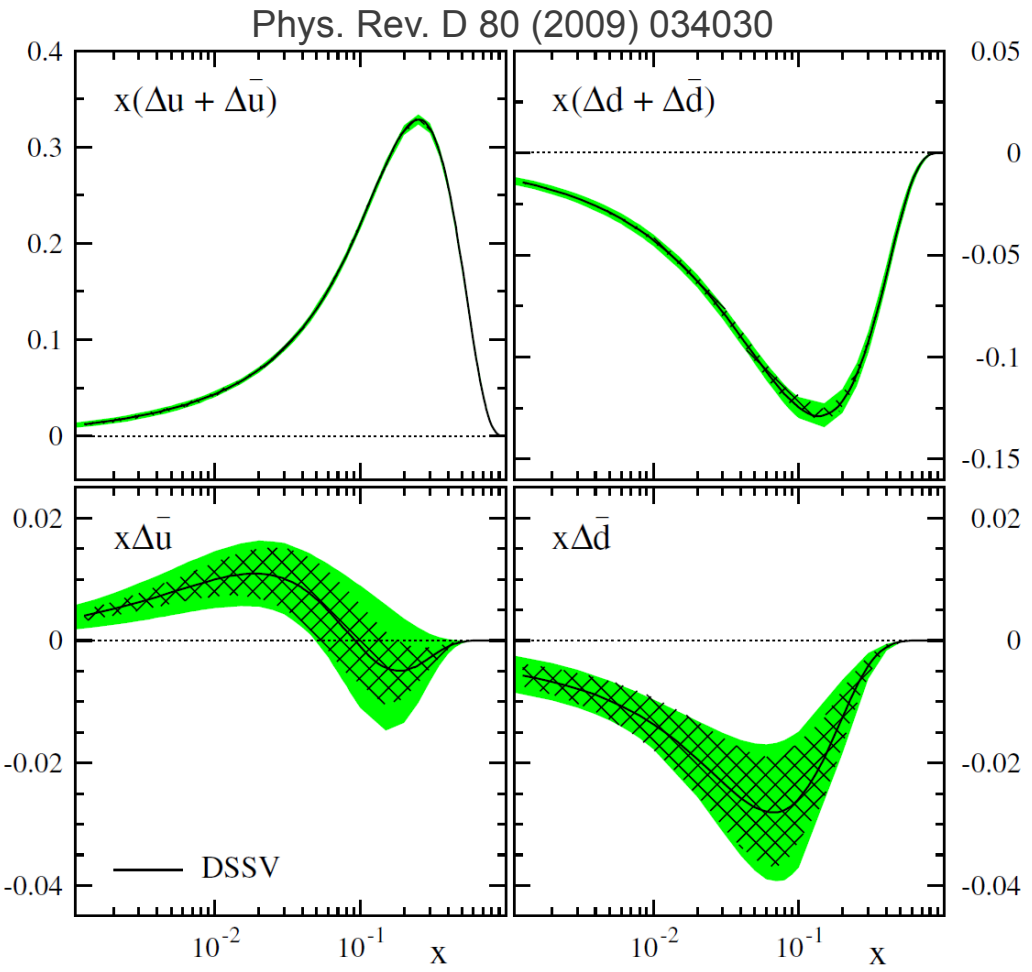
gluon

Spin = ½
u+u+d+++ = ½ ?



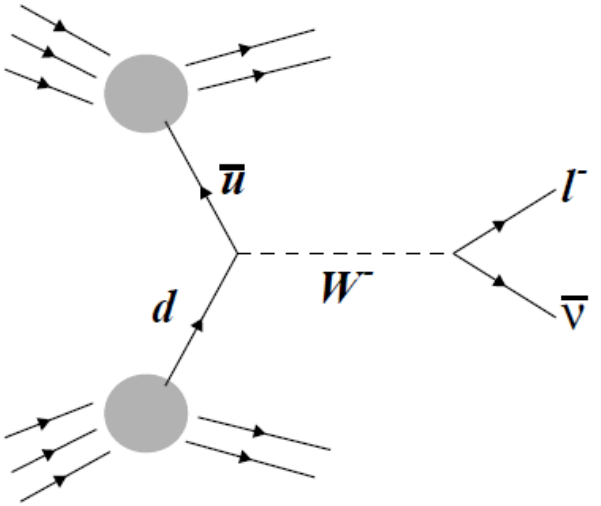
Sea quark contribution

- One missing piece – sea polarization
  - Quark polarized PDFs well constrained in fit to world data
  - Sea-quark → only roughly known
- Errors represent fit uncertainty
  - lack of data and
  - model uncertainties in fragmentation functions

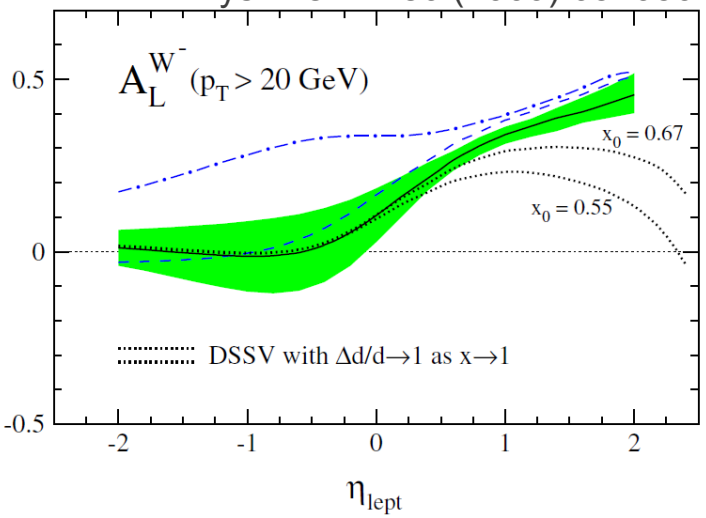


W as a unique probe

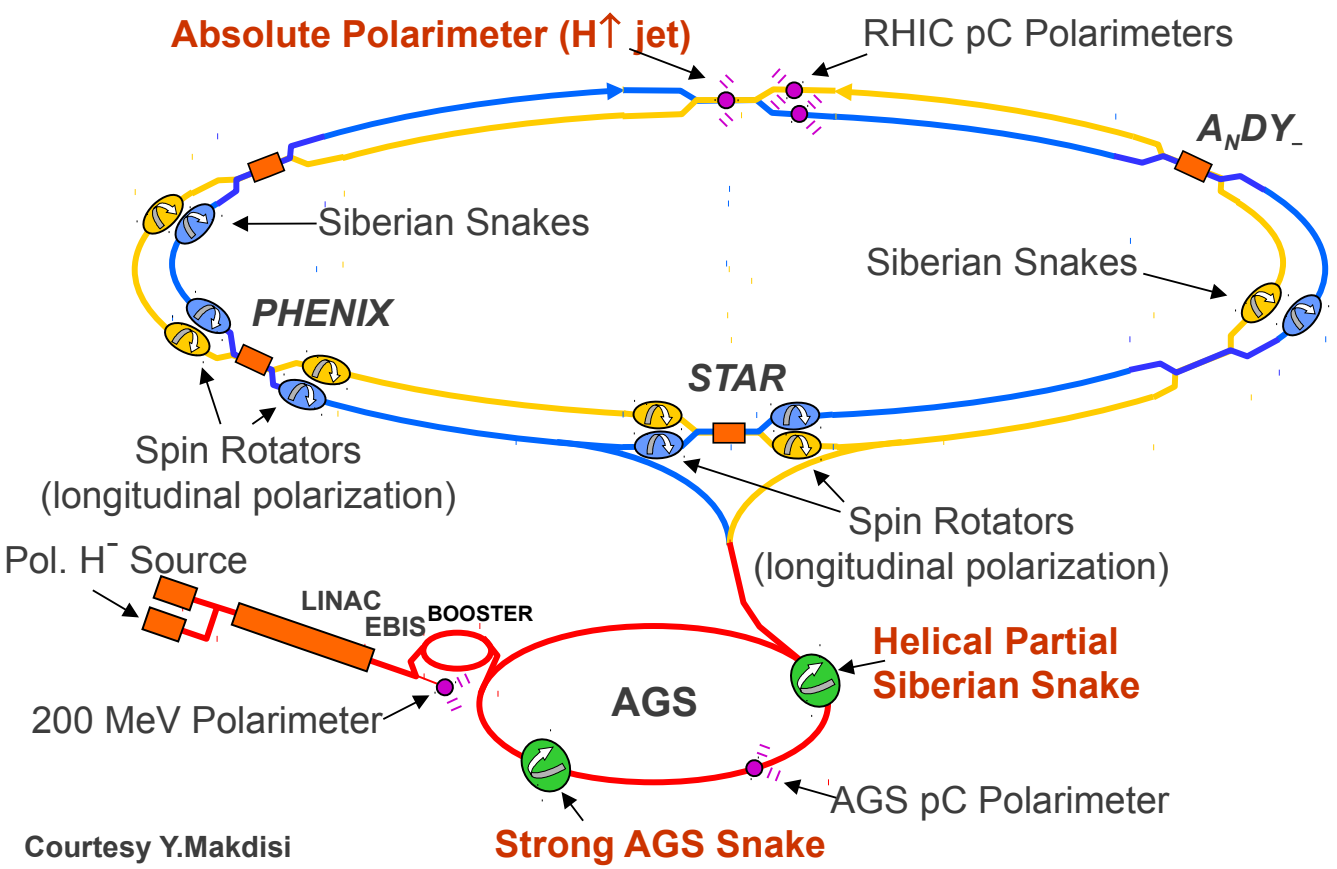
- W's provide a clean probe of the sea
  - Maximally parity violating
  - Measure decay leptons
- W+: probes d-bar contribution
- W–: probes u-bar contribution



Phys. Rev. D 80 (2009) 034030



RHIC Spin

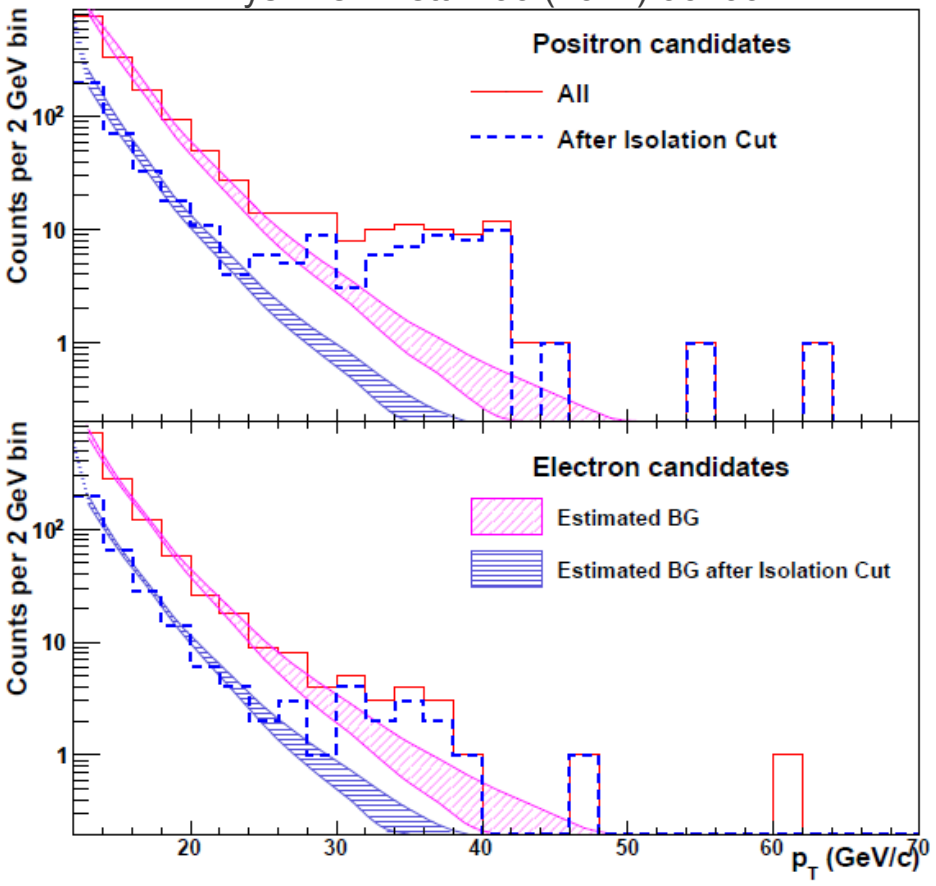


- Polarized protons from 200-500 GeV
- Longitudinal and transverse running

- Two systematic advantages:
  - Siberian snakes: reduce depolarizing resonances
  - Alternating spin pattern (reduces uncertainty in relative luminosity due to positive/negative helicity)

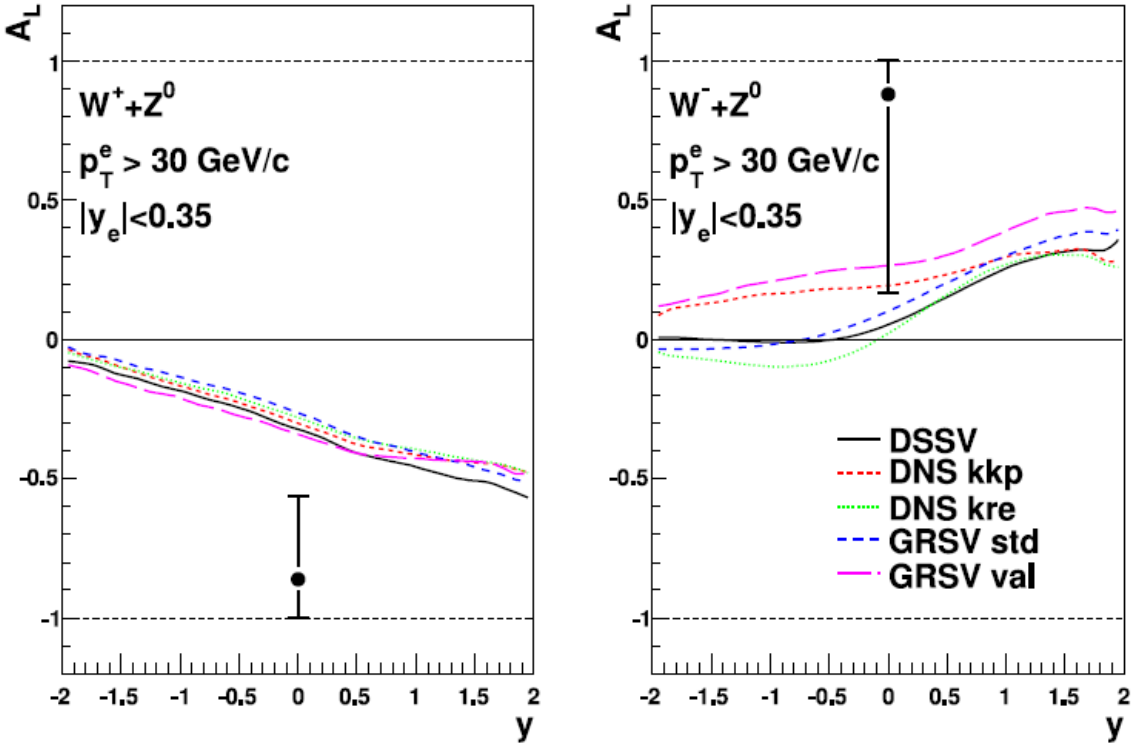
Central-arm measurements (Run 9 data)

Phys. Rev. Lett. 106 (2011) 062001



- First measurements of W cross-section and single spin asymmetries at RHIC
  - From both PHENIX and STAR
- Jacobian peak clearly visible at large momenta

Results and Forward expectations



$$\epsilon_L = \frac{N^+ - R \cdot N^-}{N^+ + R \cdot N^-}$$

Measured Asymmetry

$$A_L = \frac{\epsilon_L \cdot D}{P}$$

Corrected Asymmetry

- First measurement of electron single spin asymmetries at central rapidities (Run9)
  - $W^{\pm}$ and Z^0 indistinguishable
- More data available from Run11 and Run12
- Larger asymmetries expected at higher rapidity

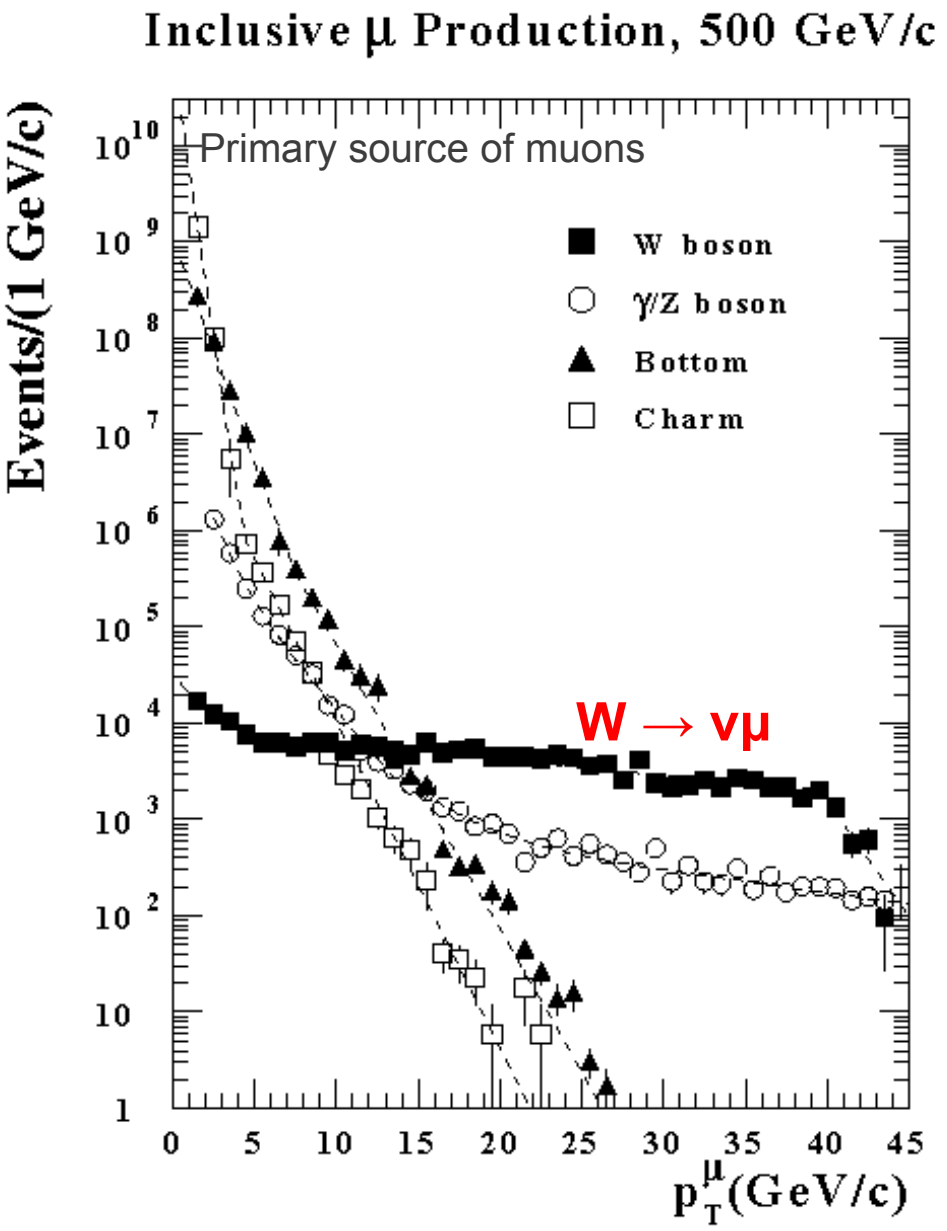
Forward Analysis Plan

- Measure forward muons
  - Large asymmetry expected
  - PHENIX already has a forward muon detector

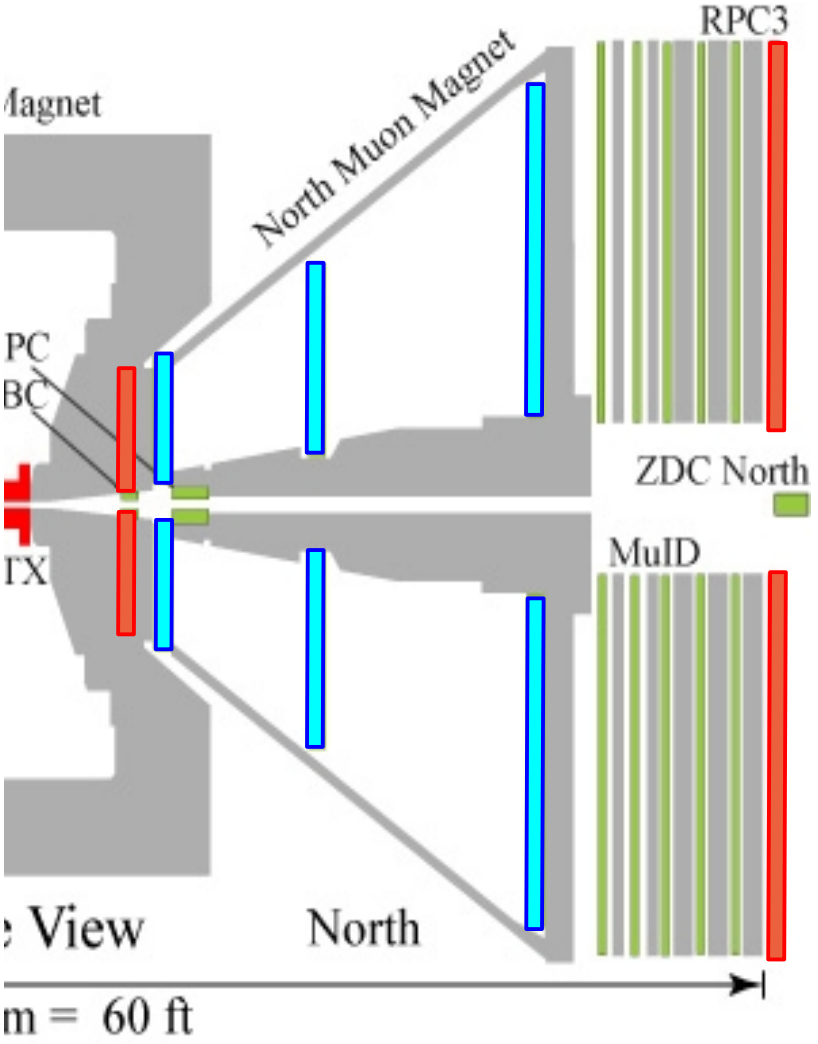
- Caveats
  - Muon arms proven only at low momentum
  - Large low-momentum muon cross-section from background sources
    - Need to trigger on high-momentum tracks

Before upgrade

- Trigger on MuID only
  - All p>2GeV/*c* survive
  - Dominated by low-p_T muon track candidates
- Solution: add the capability to select only high-momentum tracks



Upgrade (2009-2012)

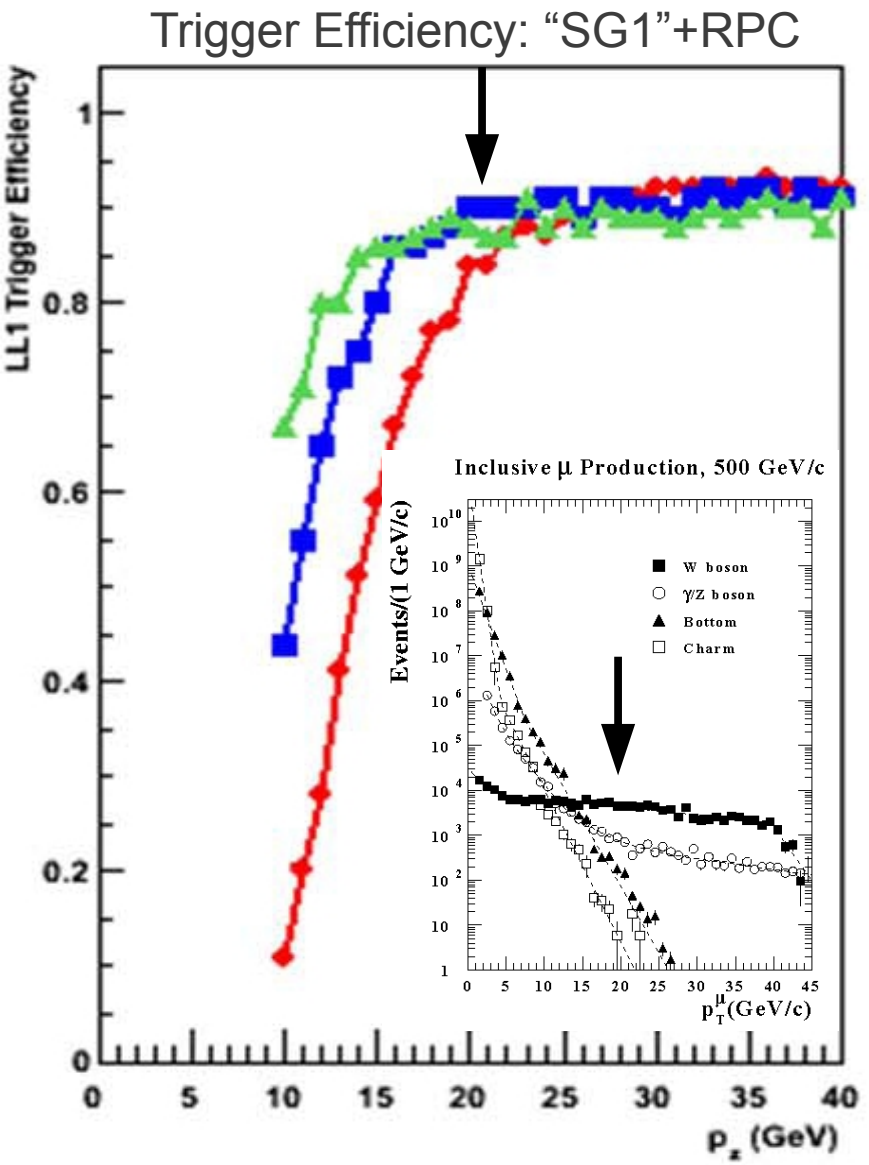


- Front-End Electronics Upgrade to muon tracker
  - Trigger minimum momentum
- Additional Resistive Plate Chambers
  - Time measurement relative to crossing
  - Spatial measurement in η and φ

- For both muon arms, only North arm is shown
- Construction competed with ongoing commissioning in Run12

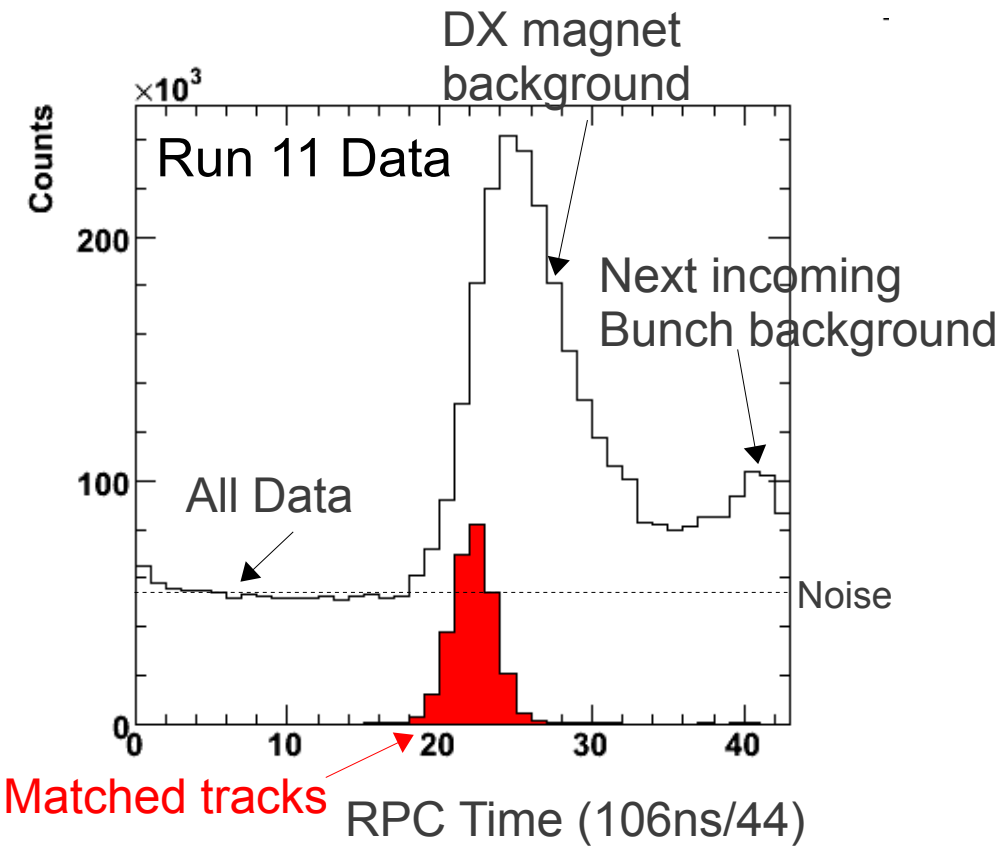
After upgrade

- Trigger on straight-line tracks through the whole muon arm
  - Excludes low-momentum muons
- SG1 → allows a bend in the muon tracker of 1 strip
  - Leads to a momentum cut of about 10-15GeV/c



Background rejection

- RPC's allow one to reject some backgrounds
  - Matched tracks at fixed time
  - Backgrounds from DX magnets and incoming beam bunch are separable.
- Narrow time window in trigger further improves on trigger rejection



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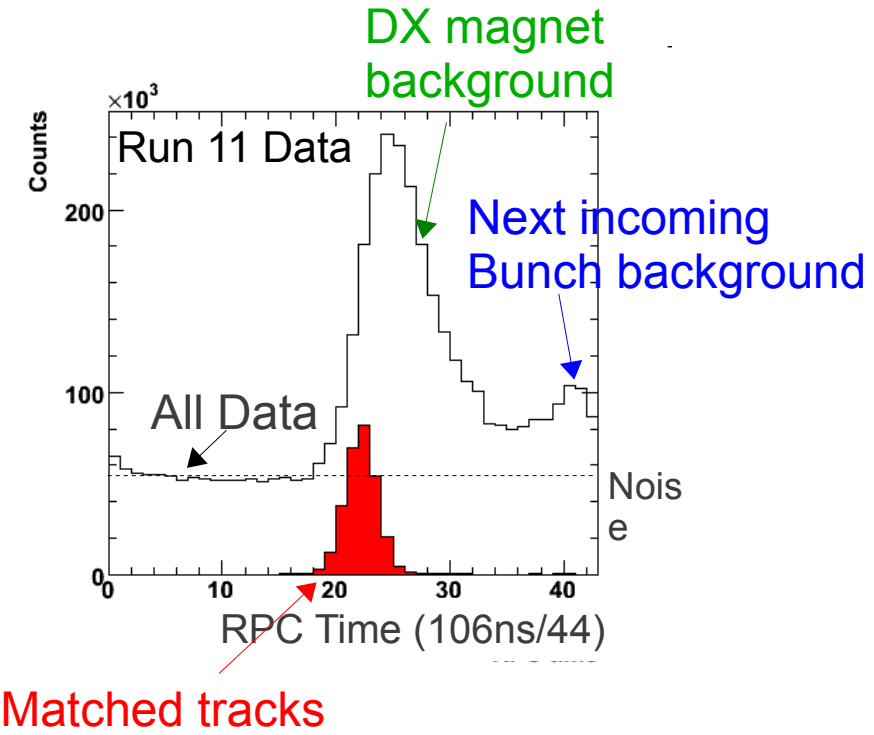
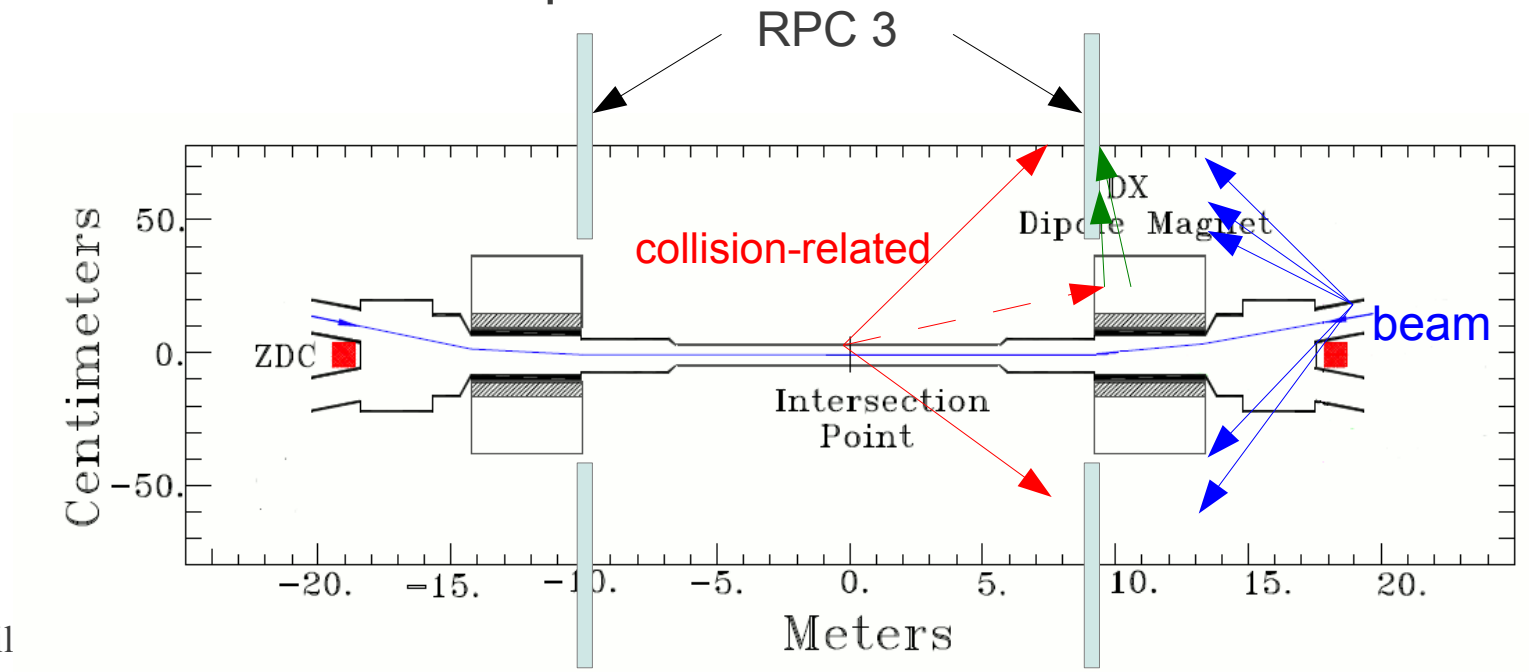
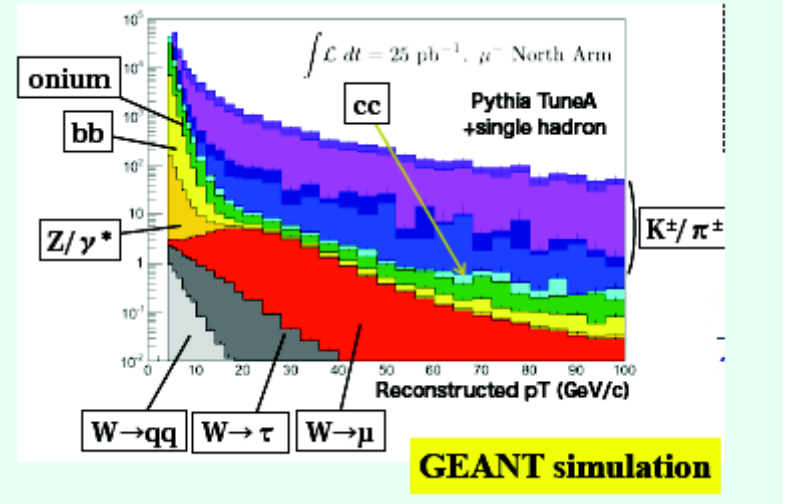


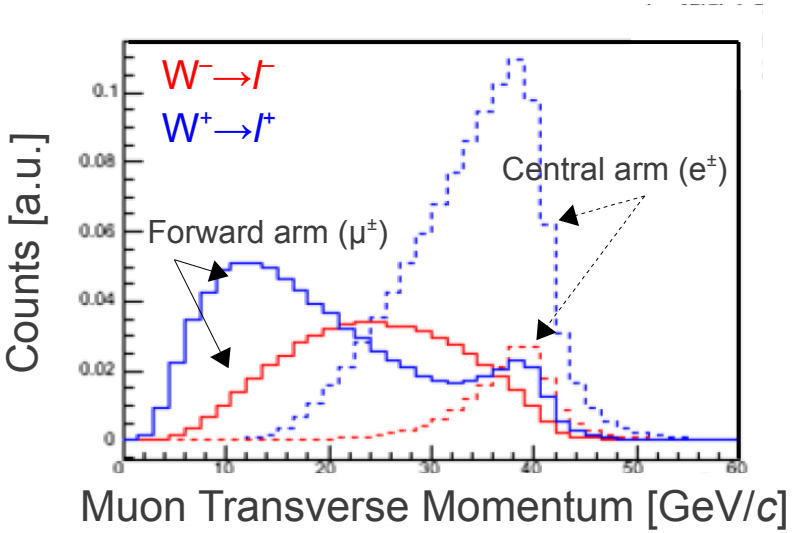


Understanding Backgrounds

- Background and Signal spectral shapes are not dissimilar
  - No Jacobian peak to help distinguish signal from background level

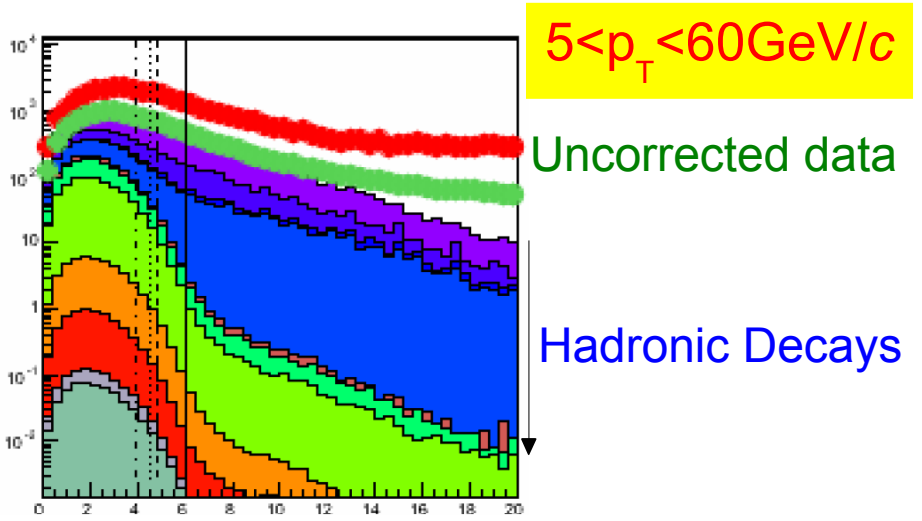


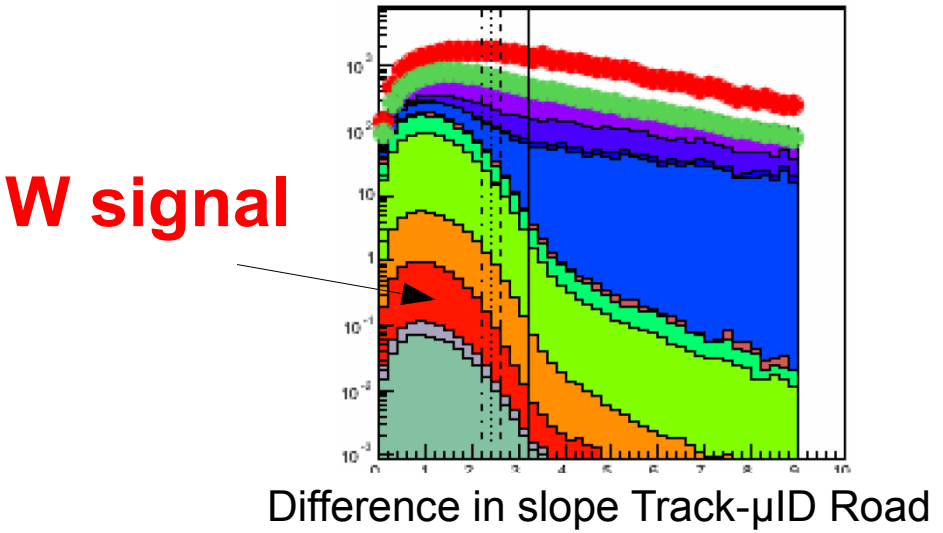
- Two issues:
  - Dominating fake background from low-p_T hadrons
  - Momentum smearing in muon arms



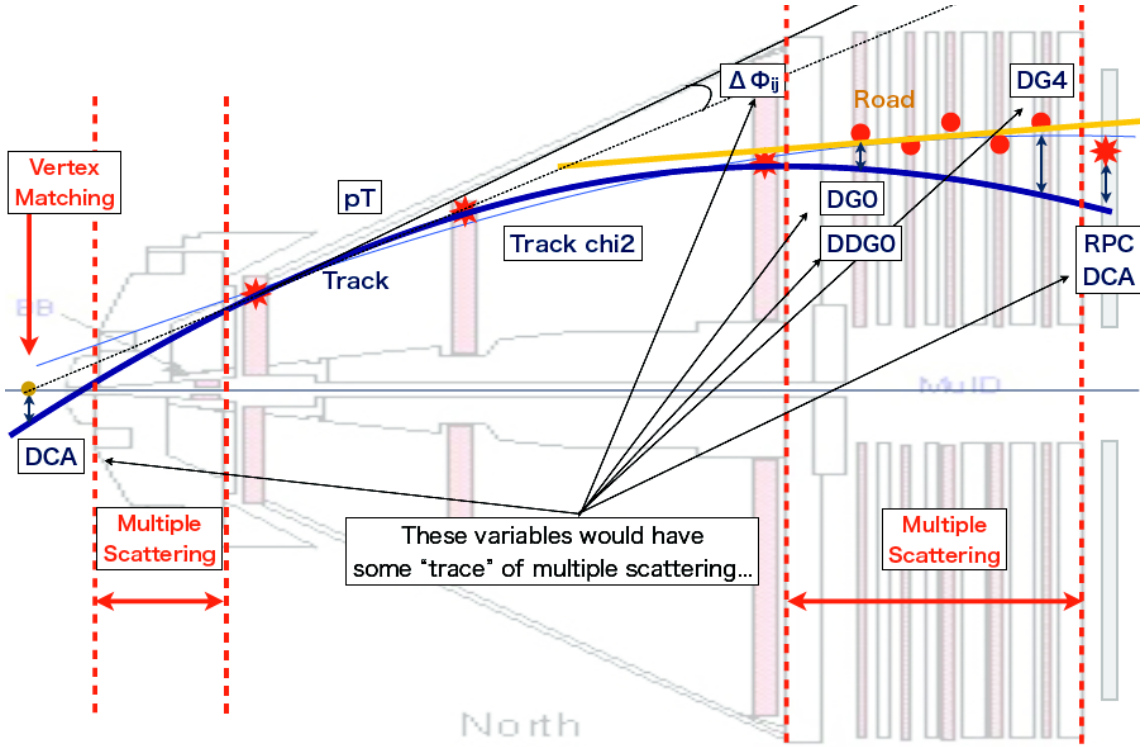
Track Quality Cuts

- Main defense against fake background
- Low-momentum hadrons typically have a different residual distribution
  - Cut to retain 90% (tightest cut) to 99% (loosest) muons





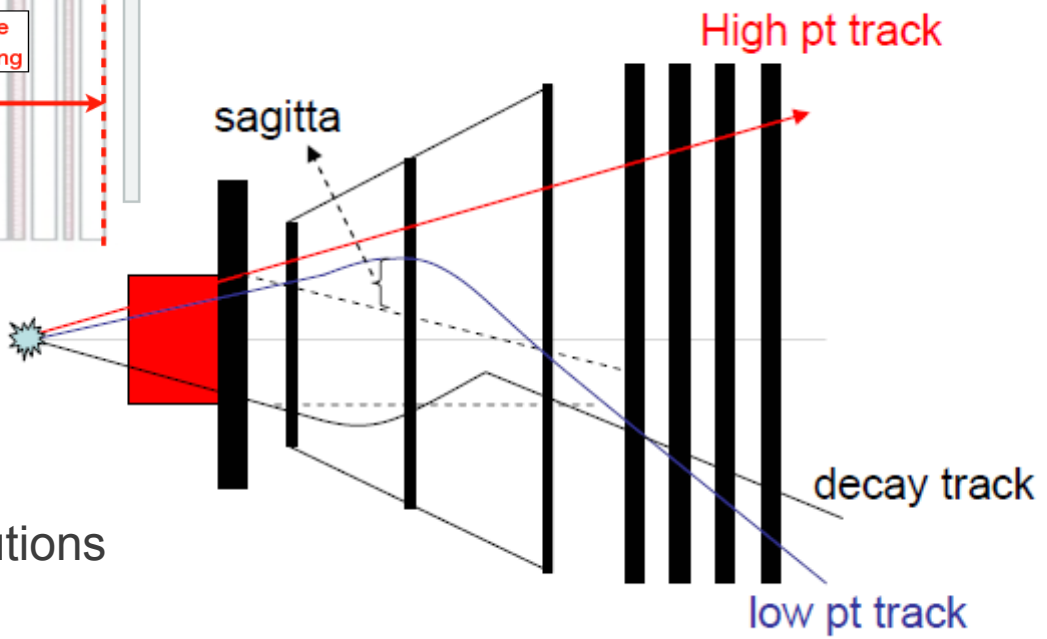
Track Quality Cuts



Reduce background by requiring each cut to retain

90%, 95%, 97%, or 99%

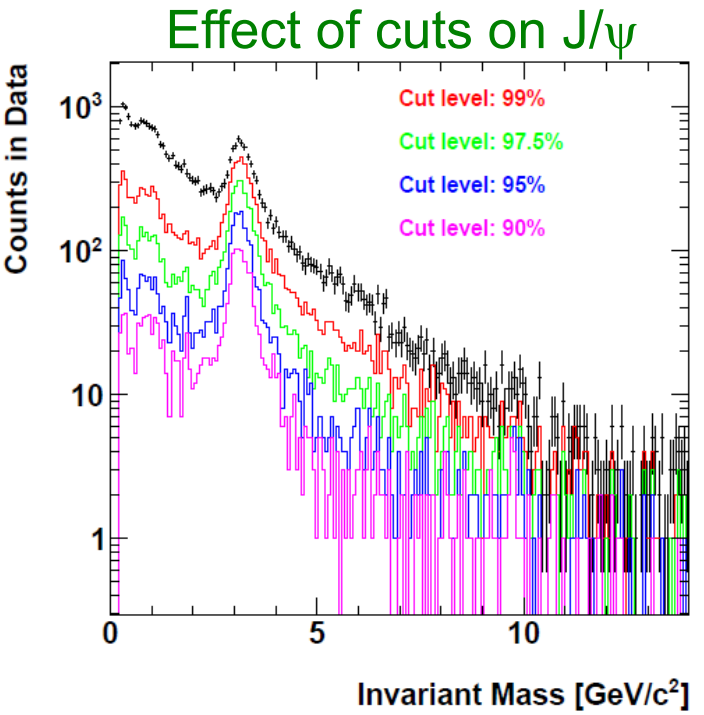
of signal muons



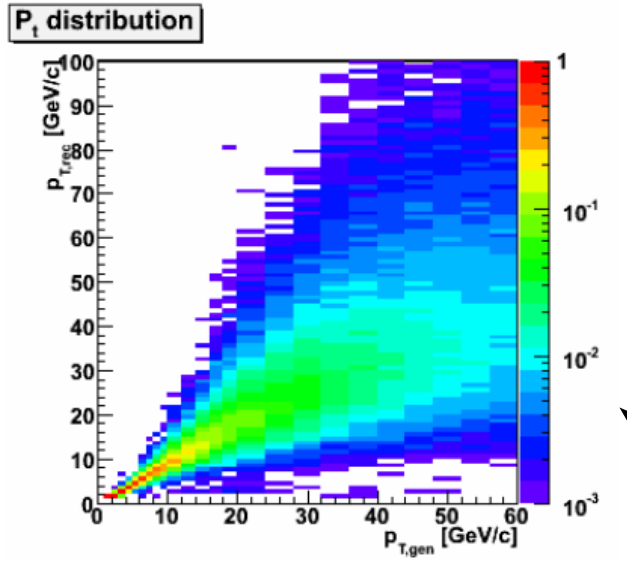
Fake background → wider residual distributions

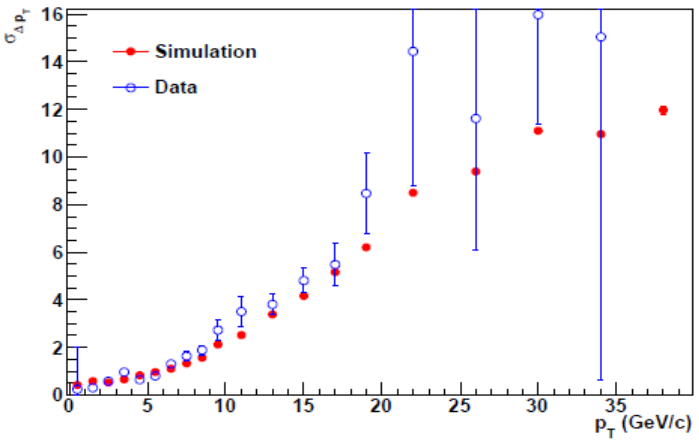
Track Quality Cuts

- Rely mostly on simulations to provide cut positions
  - Checked with real muons from J/ψ decays (low-p)
  - Checked with cosmic muons (high-p)



Simulations and Cosmic-Rays

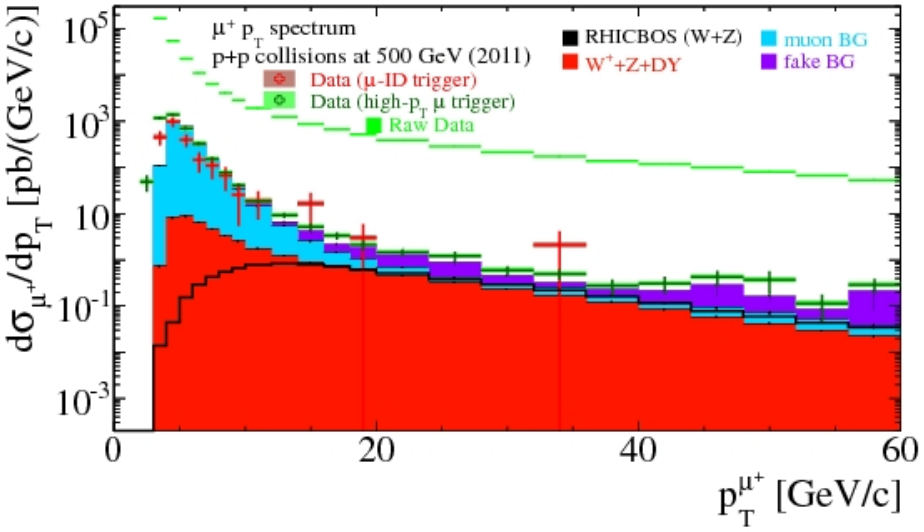




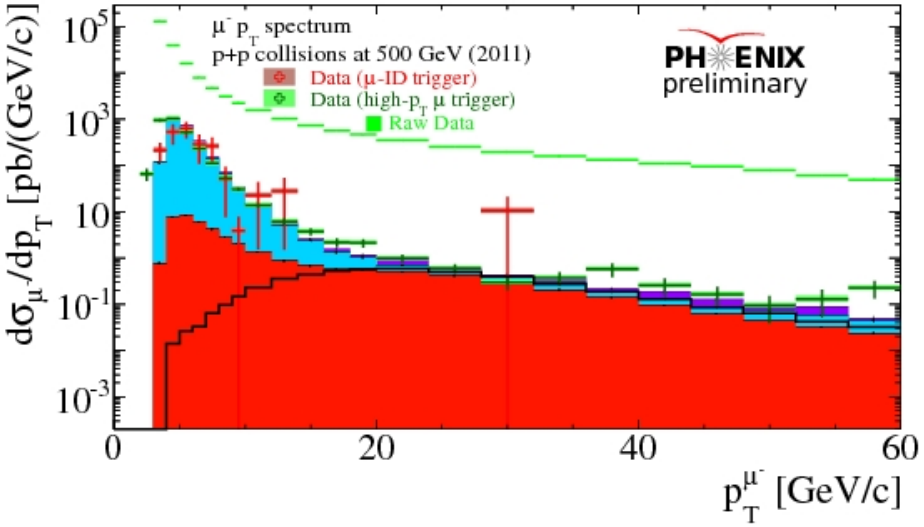
- Significant smearing at large momentum
  - Use cosmic rays through both muon-arms to evaluate detector response in simulations
- Single muon simulation
  - Reconstructed versus true momentum
- Simulated (red) and back-to-back cosmic-ray muons (blue)

μ Cross-section

- Data and expected simulated μ cross-section
  - W→μ signal
  - Irreducible background
  - Fake background



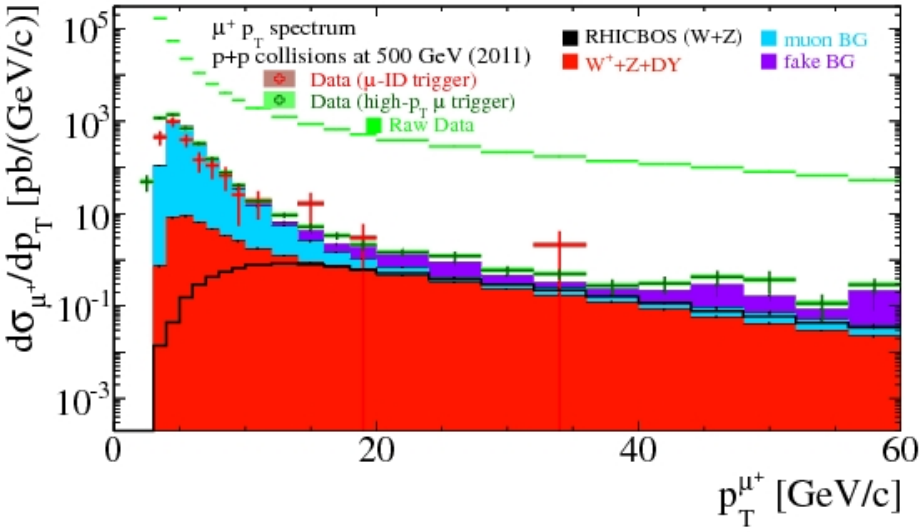
- Data are reduced by ~2-3 orders of magnitude
  - Good agreement with simulation
- Residual signal to background ~1:3 (p_T>15GeV/*c*)
  - Starts at 1:>300 (p_T>15GeV/*c*)

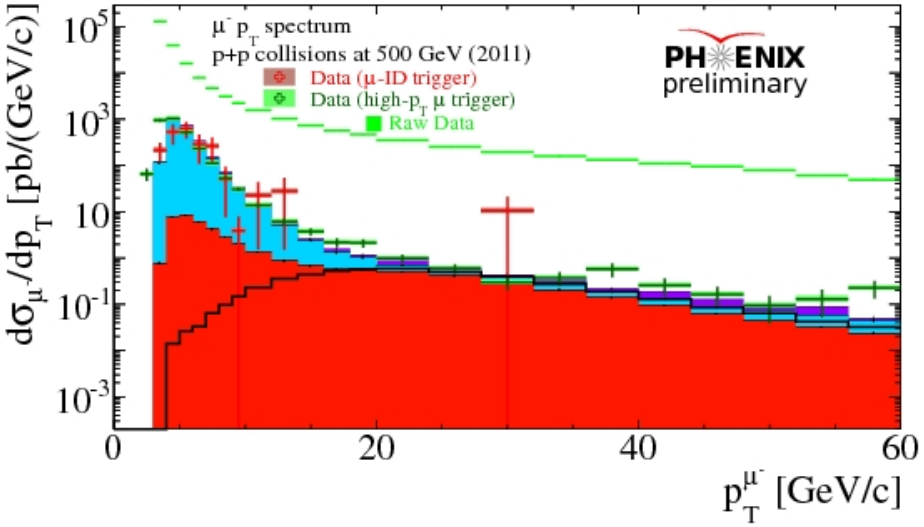


Signal-to-Background

- Need to estimate signal-to-background for the dilution factor
- Two methods
  - Simulation only
  - Simulation (signal) and data (signal+background)

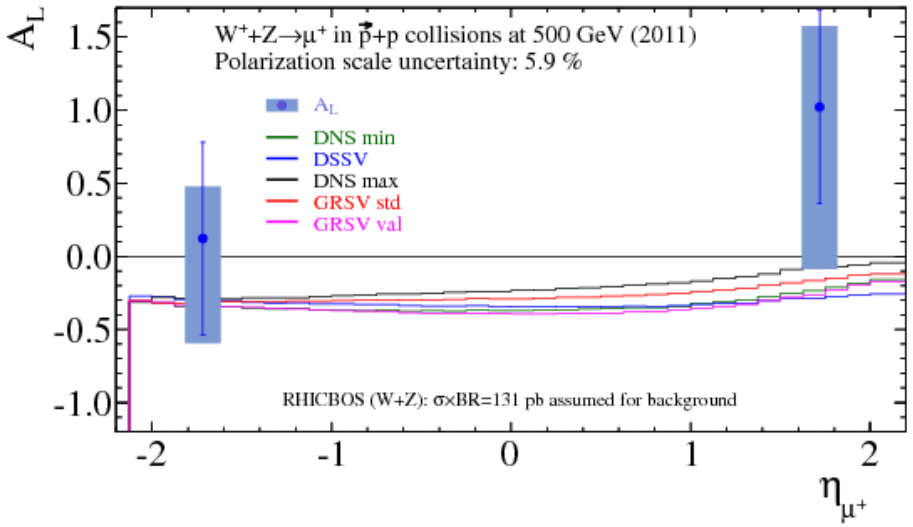
- Zero checks:
  - Asymmetry vanishes for loosest cuts (more background)
  - Asymmetry vanishes for lower momentum (more background)

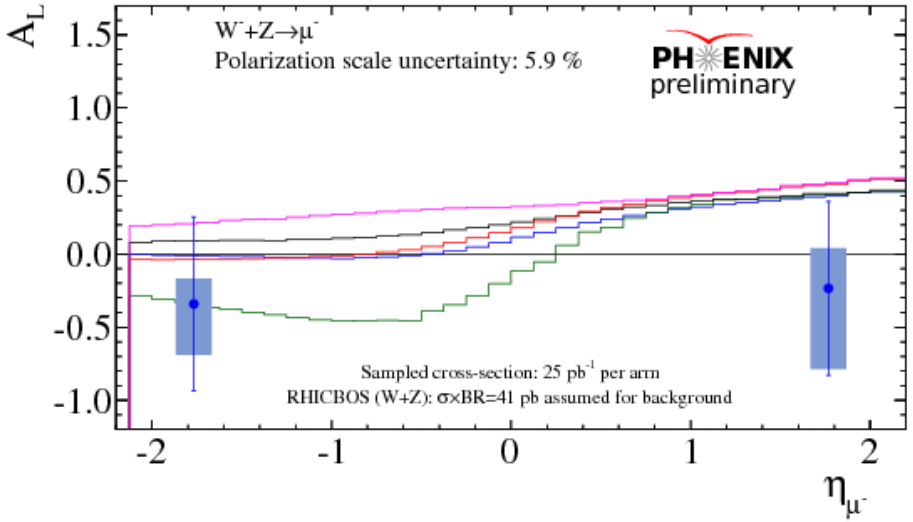




μ Asymmetries

- Forward muon single spin asymmetries
  - √s=500 GeV
  - P~50%
  - L~25pb^{-1} per arm
- Compared to RHICBOS
- Statistics limited, but currently taking more 510GeV collisions





Highlights

- First results from PHENIX's forward W program
  - More results to come from the on going 510GeV run
- New upgrades provide trigger rejection to reject low-p muons
  - Construction just completed for Run 12 (2012)
  - Commissioning still ongoing, ready for next 500GeV physics run
- Need 300pb^{-1} to complete the W program
  - To provide a direct constraint on the sea contribution to the protons' spin